N90-25507

SPACECRAFT CONTAMINATION PROGRAMS WITHIN THE AIR FORCE SYSTEMS COMMAND LABORATORIES

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ABSTRACT

Spacecraft contamination programs exist in five independent AFSC organizations: Geophysics Laboratory (Lead Laboratory), Arnold Engineering & Development Center (AEDC), Rome Air Development Center (RADC/OCSE), Wright Research & Development Center (MLBT), Armament Laboratory (ATL/SAI), and Space Systems Division (SSD/OL-AW). In addition, a sizable program exist at Aerospace Corp., an FCRC for AFSC. These programs are complementary, each effort addressing a specific area of expertise: GL's effort is aimed at addressing the effects of *on-orbit* contamination; AEDC's effort is aimed at ground simulation and measurement of optical contamination; RADC's effort addresses the accumulation, measurement, and removal of contamination on large optics; MLBT's effort is aimed at understanding the effect of contamination on materials; ATL's effort is aimed at understanding the effect of plume contamination on systems; SSD's effort is confined to the integration of some contamination experiments sponsored by SSD/CLT; and Aerospace Corp.'s effort is aimed at supporting the needs of the using SPO's in specific areas, such as contamination during ground handling, ascent phase, laboratory measurements aimed at understanding on-orbit contamination, and mass loss and mass gain in on-orbit operations. These programs will be described is some detail, with emphasis on GL's program.

INTRODUCTION

Systems operating in low earth orbit, have experienced anomalies and artifacts in their observations. Some of the anomalies are attributable directly to contamination in and near the spacecraft surfaces. An example of contamination effects is the observation of gaseous contaminants in the shuttle bay which are due to the return flux of gases from thrusters fired at various locations in the Space Shuttle (Narcisi et al., 1983; Wulf and von Zahn, 1986) and the observation of enhanced ionization and suprathermal ions in the vicinity of the shuttle (Hunton and Calo, 1985; Grebowsky et al., 1987). In addition to these observations, others have been made of a closely related subject, namely the erosion of materials by atomic oxygen due to the high velocity of the ramming atmosphere (Leger and Visentine, 1986; Gregory, 1987; Leger et al., 1987; Peters et al., 1986; Peters et al., 1988). A third, and somewhat startling, contamination effect has been the report of a glow on shuttle surfaces in the ram direction (Mende et al., 1983, 1985, 1987). This latter observation has been attributed to off-surface recombination of impinging O atoms and surface adsorbed NO (Swenson,et al 1985; Swenson, 1986; Kofsky and Barrett, 1986).

DISCUSSION

These observations and reports of anomalies on a number of flights have prompted AFSC to undertake a number of different, but complementary, program to address the issue of spacecraft contamination. Listed below are the efforts in the individual laboratories and Aerospace Corp.

Arnold Engineering and Development Center (AEDC/DOTR): The focus of the work is the laboratory simulation of spacecraft contamination and the measurement of various aspects of the contaminants, such as degradataion of optical surfaces due to contamination, flowfields of plume contamination, and formation of droplets in the expansion of vapor and liquid in vacuum. The experiments are carried out in a test chamber at AEDC. Focal point for the work is AEDC/DOTR (Capt S. D. Shepherd/615-454-6517). Technical support is provided by Calspan (Mr. Bobby Wood).

Armament Laboratory (ATL/SAI): The stress of this work is on the effect of contamination generated by the return flux of plumes. As part of the work, ATL/SAI has picked up the development and support for **CONTAM 3.xx**. Focal point is Ms. Vicki Cox (ATL/SAI, 904-882-4278). Work on **CONTAM 3.xx** is carried out under contract by Dr. Ron Hoffman of Science Applications International Corp.

Rome Air Development Center (RADC/OCSE): The focus of this work is development of techniques for the measurement, mitigation, and removal of contamination from large optics. In addition, space and laboratory experiments are developed to validate these techniques. Focal point for the work is Capt Carol Moreland/315-330-3145). Technical support is provided by W. J. Schaeffer Associates (Dr. Keith Shillito).

Wright Research & Development Center (WRDC/ MLBT): The focus of this effort is the development of a database for spacecraft contamination as well as the measurement of contamination effects on materials. Focal point for the effort is Lt Arthur Estavillo (WRDC/MLBT/513-255-9022). Some technical support is provided by Aerospace Corp.

Aerospace Corp.: Aerospace Corp. has a large program to address ground-based contamination of spacecraft payloads, ascent phase spacecraft contamination, and some effects of on-orbit contamination. The work includes theoretical studies, laboratory work on fundamental rate processes, and space experiments. The focal point for the work is Dr. Graham Arnold (Aerospace Corp./MS M2-271/213-336-1935).

Geophysics Laboratory (GL/PHK): The work at GL is concerned mostly with effects of on-orbit contamination. Focal point for the work is at GL/PHK (Dr. Edmond Murad/617-377-3176). Below is a somewhat detailed description of the various parts of the effort:

Shuttle Glow: This work is aimed at understanding the nature and the cause of the Shuttle Glow phenomenon. Towards that end GL/PHK has undertaken a program for the development of high resolution spectrographs which will yield spectra over the range 115-1100 nanometers with a resolution of 0.35-1 nanometers, depending on the region. Two such instruments have been built; one will fly as part of the STS-39 mission, and the other is built for flight as a hitchhiker instrument. In addition, a hand-held camera responsive in the visible and operated by astronauts from the astronauts' bay has been flown. A new version of the latter camera will provide spectra in the visible region of the spectrum at a resolution of 0.9 nanoameters.

Particulates: An experiment to obtain photographs using a stereo camera system with a strobe light was flown. One of the cameras did not work so that only monographic pictures were obtained. Nonetheless, it was possible to obtain great deal of information about the time history of particulates in the shuttle environment, effect of sunlight and operations (e.g. satellite deployment) on the particulate environment of the space shuttle. This work was published (Green et al.,1987). As part of this work we recently conducted a dedicated water release experiment over the AMOS Observatory at Mt. Haleakala, HI. In this case we observed the formation of dense cloud of ice particles which extended for about 1.6 km and which had a width of about 0.6 km. Evaporation seemd to be a major loss mechanism. A manuscript covering this work is in preparation.

Gaseous Contamination: Some measurements of the composition of the gaseous cloud in the bay of the Space Shuttle have been performed using a quadrupole mass spectrometer. The work is carried out in the Ionospheric Physics Division (Dr. D. Hunton, GL/LID, 617-377-3048). Some of this work has been published (Narcisi et al., 1983; Hunton and Calo, 1985). In addition plans are underway to use the imager/spectrograph described above for the measurement of composition using optical techniques.

Laboratory Experiments: Work is underway to develop a source of ground state O atoms whose energy can be varied from 2 eV to 10 eV. This work is being done at the Jet Propulsion Laboratory by Drs. Ara Chutjian and Otto Orient. In this work surface recombination as it pertains to the Shuttle glow will be studied as well as neutral-neutral gas phase chemistry. In addition to the reactions of neutral beams, a double mass spectrometer at GL is being used to measure reaction cross sections and energy distributions of ions and neutrals as a function of energy. The work is being conducted by Drs. Rainer Dressler and James Gardner.

Model Development: The end result of GL's Spacecraft Contamination Program is the development of a user-friendly *Monte Carlo* code which can be used by designers to predict the effect of contamination on the operation of experiments and systems in low earth orbit. The code which we are developing with Spectral Sciences, Inc., **SOCRATES**, has been used to predict the optical emissions in the environment of the space shuttle, as a vernier thruster is fired. Currently **SOCRATES** includes scattering and some chemical reactions. As data from the laboratory measurements become available, they will be incorporated into the code. Currently under development is the second module of **SOCRATES**, the gas-surface interactions model. In a third, and final, module of the code we intend to incorporate ion-neutral collisions. The main developer of the code is Dr. J. Elgin of Spectral Sciences, Inc.

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